6.0 Water Balance

A water balance was performed for virgin (undeveloped), existing and buildout conditions to evaluate the impacts of development on the water cycle and to evaluate how the proposed overlays and performance criteria for adoption address these impacts to protect and sustain the health of the Town's watershed hydrologic cycle. Water balances for virgin and existing conditions were performed strictly as a point of comparison, since it is not realistic to assume that these conditions can be met under a buildout scenario, even with performance criteria in place.

The study area was broken into nine subwatersheds (Figure 2-3) to allow for the evaluation of flows in and out of various areas of the Town. The subwatershed divisions were based on USGS topography and the locations of prominent water bodies.

The water balance considered three factors: 1) precipitation and stormwater (stormwater runoff, recharge and evapotranspiration); 2) wastewater imports and exports; and 3) water withdrawals. A simple mass balance equation was used to evaluate recharge as follows:

$$Re = P - ET - Q$$

Where:

Re = Recharge
P = Annual precipitation
ET = Evapotranspiration
Q = Runoff

The water balance was then evaluated using the following simplified mass balance equation:

$$GW = Re + WWG - WS - WWE$$

Where:

GW = Available groundwater for baseflow
Re = Recharge
WWG = Total wastewater generated (includes wastewater generated from septic systems that remain within the study area, as well as sewer systems that export water from the study area)
WS = Water supply withdrawals
WWE = Wastewater exports out of subwatershed (this is the sewered portion that leaves the study area)

The following explains the assumptions used to calculate each of these three factors:

Precipitation and Stormwater

Average annual precipitation is 49.5 inches/year on average. Precipitation was converted into gallons of water entering the study area on an annual basis by multiplying the precipitation by the total land area for each zoning district in each subwatershed. The remaining developable land areas calculated for existing conditions and buildout analysis with GIS were then broken up into typical components, including impervious, lawn and forest. The assumptions used in these calculations are provided in the following table.

Percent Land Type Used in Water Balance			
	Residential	Limited Office	Light Industry
Land Type			
Impervious	14%	85%	64%
Lawn	36%	15%	30%
Forest	50%	0%	6%

Runoff coefficients were then developed for each land use and soil type. These are summarized in the following table:

Runoff Coefficients Used in Water Balance								
Soil Type	**Forested**	**Impervious**	**Lawn Residential**	**Lawn Limited Office & Light Industrial**	**Wetland**	**Flood Plain**	**Roads**	**Water**
A	0.059	0.95	0.18	0.05			0.75	0.95
B	0.11	0.95	0.20	0.10			0.75	0.95
C	0.15	0.95	0.23	0.13			0.75	0.95
D	0.20	0.95	0.25	0.17	0.75	0.2	0.75	0.95

Notes:

1. The lawn runoff coefficients for Limited Office and Light Industrial assume the majority of greenspace will be landscaped areas, which have a lower runoff coefficient than residential lawns.
2. The roads runoff coefficient represents roadways and right of ways within the study area as identified by MassGIS.

The runoff coefficients were applied to the appropriate land uses using the equation:

$Q = C*P*A*27,154$

Where:

Q = total runoff (gal/year)
C = runoff coefficient (unitless)
P = annual precipitation (inches)

A = land area (acres)
27,154 = conversion factor (43,560 sq.ft./acre*7.4805 gal/ft^3÷12 inches/ft)

Evapotranspiration was assumed to be 40% for forested areas and 25% for lawns and wetlands of the annual precipitation. This was calculated and both the runoff and evapotranspiration were subtracted from the total precipitation to estimate annual recharge for a given area. The performance criteria described above were applied to the precipitation/stormwater runoff balance. The results are summarized in Table 6-1 by zoning district.

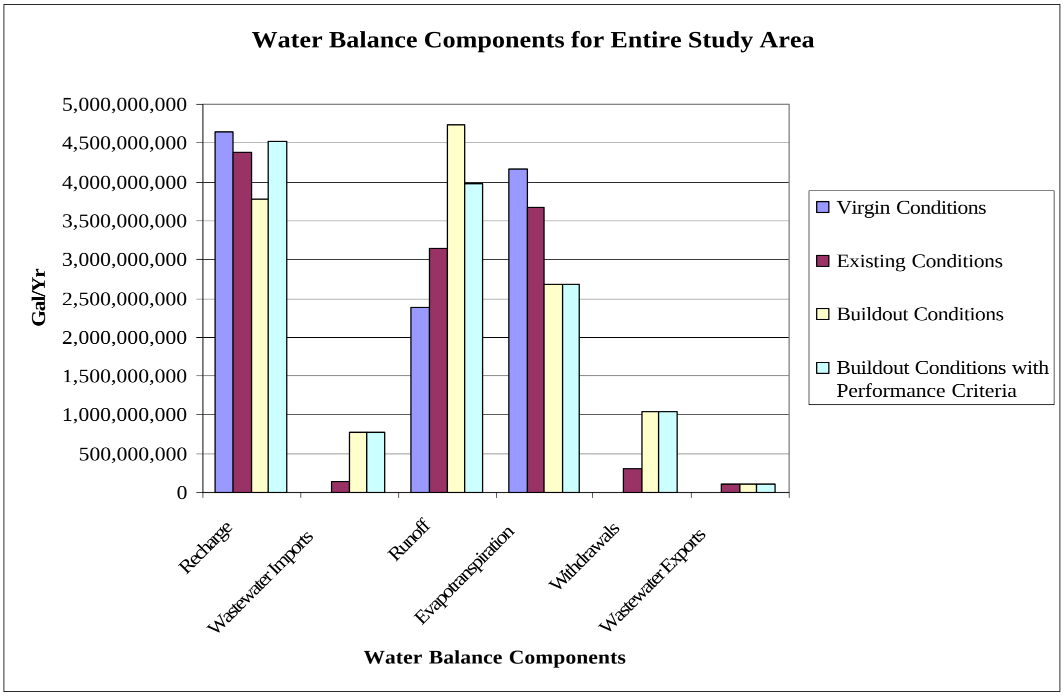
Water Withdrawals

There are no public water supply wells within the study area. Most of the drinking water is supplied through private wells, however, there are several existing properties located along Route 117 that are on the municipal water supply. The municipal water supply source is located outside of the study area, therefore water consumption associated with these properties was excluded from the water balance. It was assumed for buildout purposes that future development would be supplied with private water supply wells since Lancaster's water supply is already at capacity. To estimate the withdrawals occurring from private systems, it was assumed that 75 gallons per capita per day was consumed. This is an assumption used by EOEA in their buildout analysis. DEP is pushing for 65 gpcpd in high and medium stressed basins, but this can be difficult and may take some time to achieve. A summary of the results of this analysis are provided in Table 6-2.

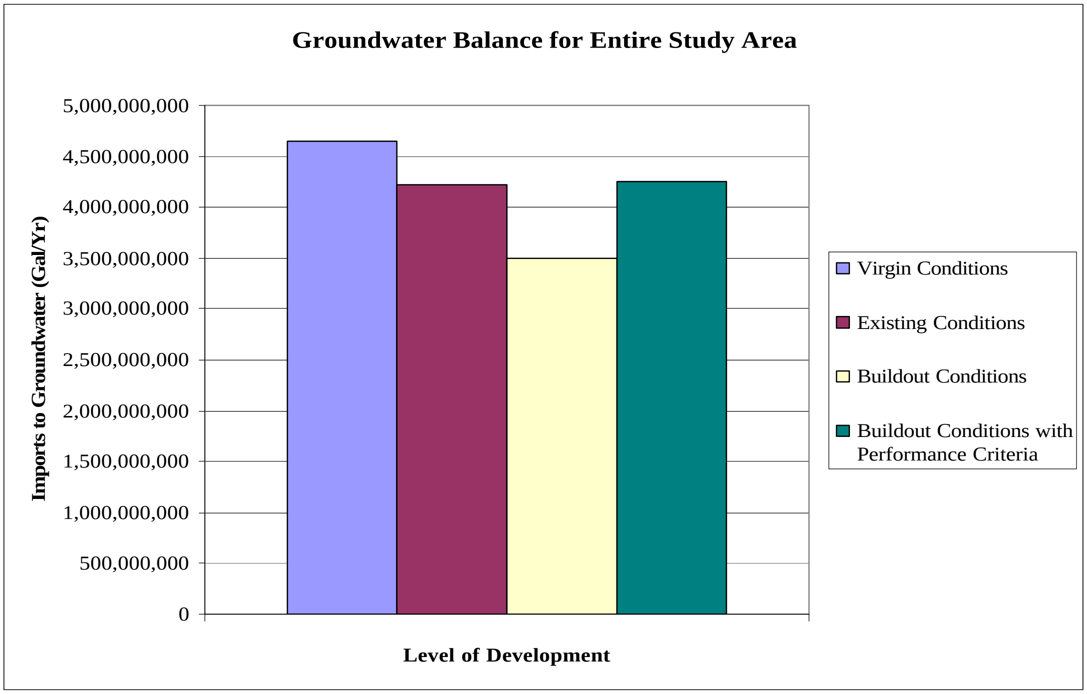
Wastewater Imports and Exports

Wastewater imports and exports into the study area were also evaluated. Currently, all but one development within the study area uses an on-site wastewater disposal system. The Division of Youth Services in the Shaker Hill subwatershed discharges their waste to the Devens Community wastewater treatment facility. Both wastewater imports and wastewater exports are reflected in the table to show how much is retained within the study area and the quantity that leaves the study area. It was assumed for buildout purposes that no additional sewering would be provided and all wastewater would be handled on-site, resulting in no additional losses from wastewater. Other alternatives that consider sewering will be considered under the Integrated Water Resources Management (IWRM) plan. A summary of the results of this analysis are provided in Table 6-3.

A complete water balance for the study area was completed using the individual stormwater, water and wastewater analyses. The components involved in the water balance are provided in Table 6-4. Table 6-5 shows the total water balance based on the equation provided above and represents the amount of water that would be recharged into the groundwater. The following figure summarizes the annual water balance components for the study area under virgin, existing, buildout and regulated buildout (overlay and performance criteria) conditions.



The following figure shows the groundwater balance for the entire study area and represents the amount of water that would normally infiltrate through the ground to replenish groundwater.



The results show a significant increase in the amount of water retained within the subwatershed when the performance criteria are applied versus the buildout conditions without any BMP standards applied. The performance criteria also help to maintain existing conditions at buildout. The majority of water losses can be attributed to stormwater runoff associated with development. The losses from water withdrawals are minor in comparison for this particular study area. This emphasizes the importance of an overlay district and performance criteria to control the stormwater impacts from development in the study area.

Additionally, the proposed criteria will assist with cooling stormwater runoff by requiring the majority of storms to discharge through an underdrain system. A study by Maine Department of Environmental Protection found the temperature within a wet pond to cool by 15 degrees Fahrenheit by discharging through an underdrain structure (personal communication, Jeff Dennis, 2006).

The following figure shows a breakdown of the water balance by subwatershed for virgin, existing, buildout and regulated buildout conditions. The data is summarized in Table 6-6. The detailed analyses by subwatershed are provided in Appendix A.

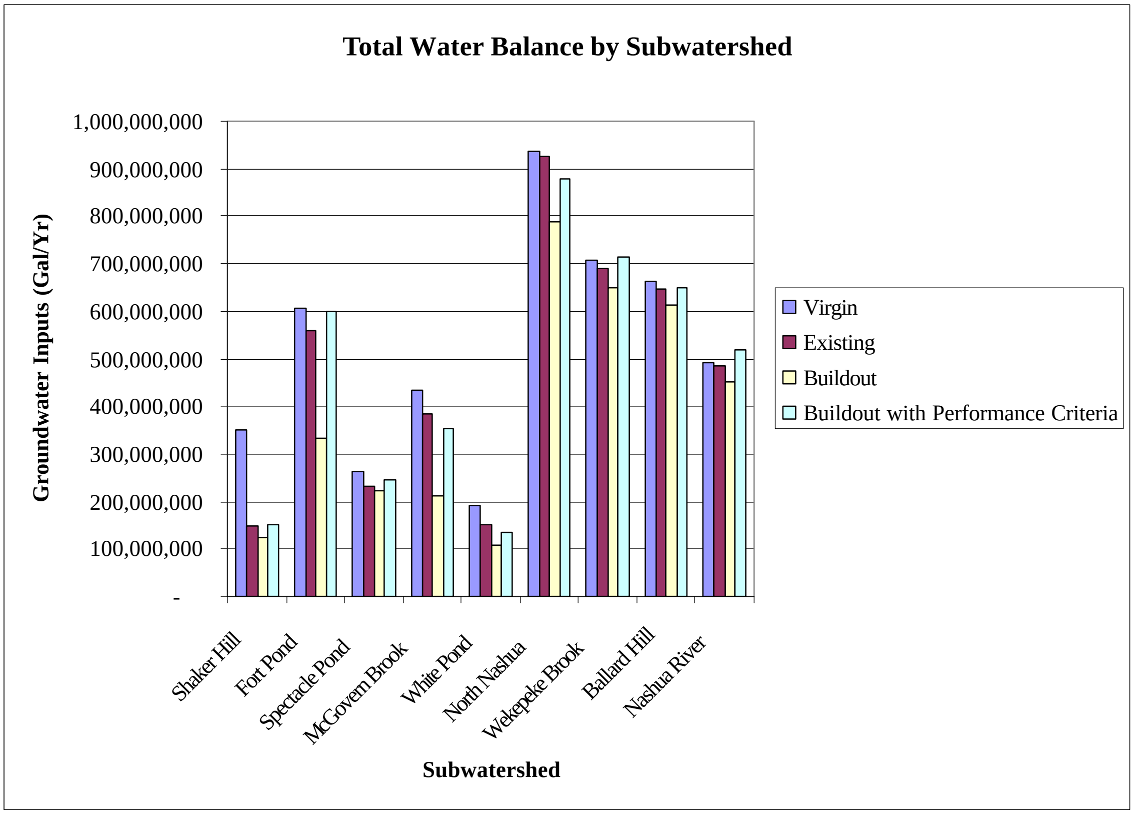


Table 6-1. Precipitation Water Balance for Entire Study Area (gal/yr)

	Residential		Limited Office		Light Industry		Roads/Water		Total		
	Existing	Buildout	Existing	Buildout	Existing	Buildout	Existing	Buildout	Existing	Buildout	Buildout with Performance Criteria
Precipitation	8,166,290,128	8,166,290,128	893,973,339	893,973,339	1,226,789,431	1,226,789,431	902,541,250	902,541,250	11,189,594,149	11,189,594,149	11,189,594,149
Runoff	1,768,217,185	2,526,264,926	309,994,737	700,951,648	312,051,536	753,962,411	747,066,111	747,066,111	3,137,329,570	4,728,245,096	3,979,321,564
Evapotranspiration	2,989,055,338	2,431,617,804	276,106,239	80,576,507	412,971,773	173,515,545	-	-	3,678,133,350	2,685,709,856	2,685,709,856
Recharge	3,409,017,605	3,208,407,398	307,872,363	112,445,184	501,766,122	299,311,476	155,475,139	155,475,139	4,374,131,229	3,775,639,196	4,524,562,728

Table 6-2. Water Withdrawals for Entire Study Area (gal/yr)

	Residential		Limited Office		Light Industry		Total Water Withdrawals Generation		
	Existing Development	Additional Development	Existing Development	Additional Development	Existing Development	Additional Development	Existing Development	Additional Development	Buildout
No. of Lots	859	1,404							
Building Square Footage			6,331,234	9,713,858	2,681,650	11,696,716			
Water Consumption	50,052,450	164,720,850	173,317,529	265,916,851	73,410,165	320,197,606	296,780,145	750,835,307	1,047,615,452

Table 6-3. Wastewater Generation for Entire Study Area (gal/yr)

Residential		Limited Office		Light Industry		Total Wastewater Generation		
Existing Development	Additional Development	Existing Development	Additional Development	Existing Development	Additional Development	Existing Development	Additional Development	Buildout
61,452,860	153,739,460	138,654,024	212,733,481	58,728,132	256,158,085	258,835,016	622,631,026	881,466,041

Table 6-4. Water Balance Components for Entire Study Area (gal/yr)

	Recharge	Wastewater Imports	Runoff	Evapotranspiration	Withdrawals	Wastewater Exports
Virgin Conditions	4,640,777,461	0	2,387,509,875	4,161,306,812	0	0
Existing Conditions	4,374,131,229	146,550,102	3,137,329,570	3,678,133,350	296,780,145	112,284,913
Buildout Conditions	3,775,639,196	769,181,128	4,728,245,096	2,685,709,856	1,047,615,452	112,284,913
Buildout Conditions with Performance Criteria	4,524,562,728	769,181,128	3,979,321,564	2,685,709,856	1,047,615,452	112,284,913

Table 6-5. Groundwater Balance for Entire Study Area (gal/yr)

	Recharge	Wastewater Imports	Withdrawals	Wastewater Exports	Total Water Balance
Virgin Conditions	4,640,777,461	0	0	0	4,640,777,461
Existing Conditions	4,374,131,229	146,550,102	296,780,145	112,284,913	4,223,901,187
Buildout Conditions	3,775,639,196	769,181,128	1,047,615,452	112,284,913	3,497,204,873
Buildout Conditions with Performance Criteria	4,524,562,728	769,181,128	1,047,615,452	112,284,913	4,246,128,404

Water Balance Summary
Entire Study Area

Table 6-6. Total Groundwater Balance by Subwatershed (gal/yr)

	Virgin	Existing	Buildout	Buildout with Performance Criteria
Shaker Hill	350,782,404	146,796,724	123,243,864	153,063,613
Fort Pond	606,435,253	557,967,239	332,797,741	597,966,641
Spectacle Pond	261,766,445	233,706,865	221,607,133	247,437,795
McGovern Brook	432,864,036	384,071,897	211,577,368	352,904,478
White Pond	192,052,958	151,308,488	106,187,515	133,827,180
North Nashua	936,992,474	924,691,178	786,429,072	878,431,983
Wekepeke Brook	705,602,626	691,736,133	650,270,994	714,105,385
Ballard Hill	661,970,572	647,131,273	612,566,324	650,814,560
Nashua River	492,310,694	486,491,390	452,524,862	517,576,769
Total	**4,640,777,461**	**4,223,901,187**	**3,497,204,873**	**4,246,128,404**

Notes:
Some existing homes in the North Nashua River, Wekepeke Brook, Ballard Hill and Nasua River Subwatersheds are on the municipal water supply, which withdraws outside of the study area. This is reflected in the above tables.